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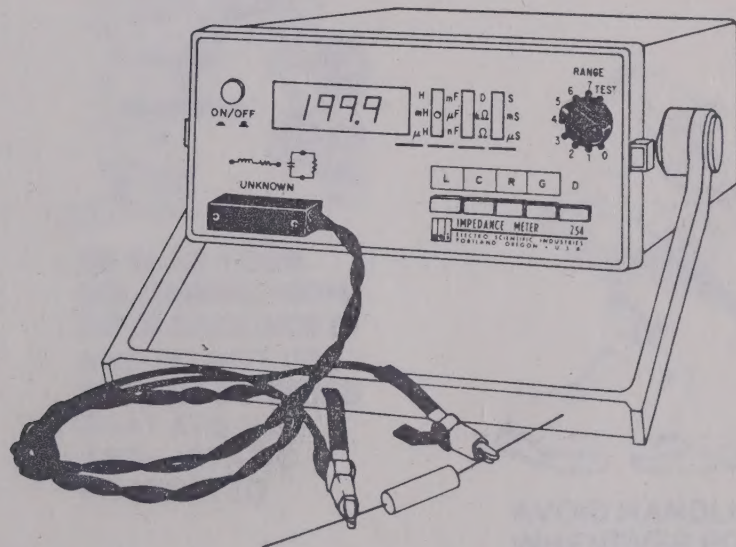
## Instruction Manual

OCTOBER 1979  
Replaces June 1979

# MODEL 254

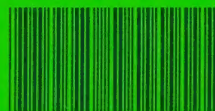
## Digital Impedance Meter

OFFICIAL RECORDS STATION  
FILE COPY  
FACILITIES  
AUG 8 1983



Part Number 43762

MP MASTER



MA30444

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# PROTECT AGAINST ELECTROSTATIC DISCHARGE

In this instrument there are MOS and FET semiconductors, which can be damaged by electrostatic discharge during handling. The following precautionary procedures are recommended to minimize this possibility.



**HANDLE STATIC SENSITIVE DEVICES ONLY AT A GROUNDED, STATIC-FREE WORK STATION**

**HANDLE DEVICES BY THE BODY. DO NOT TOUCH THE DEVICE LEADS.**



**BE SURE YOUR SOLDERING IRON TIP IS GROUNDED AND DO NOT USE SOLDER-SUCKERS THAT ARE NOT ANTI-STATIC PROTECTED**



**USE ANTI-STATIC PACKAGING FOR HANDLING AND TRANSPORT**

**KEEP PARTS IN MANUFACTURER'S PROTECTED CONTAINERS**



**DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES**



**AVOID HANDLING WHENEVER POSSIBLE**

**DO NOT SLIDE STATIC SENSITIVE DEVICES OVER ANY SURFACE AND AVOID PLASTIC, VINYL AND STYROFOAM IN WORK AREAS**





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### WARNING

DANGEROUS VOLTAGE POTENTIALS EXIST INSIDE THIS INSTRUMENT. MAINTENANCE INSTRUCTIONS WITHIN THIS MANUAL ARE FOR USE BY QUALIFIED SERVICE PERSONNEL ONLY. TO AVOID ELECTRICAL SHOCK, DO NOT ATTEMPT ANY SERVICING OTHER THAN THAT CONTAINED IN THE OPERATION INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.

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# SECTION 1

## DESCRIPTION

### 1.1 INTRODUCTION

The ESI Model 254 Digital Impedance Meter is a semi-automatic instrument which permits rapid measurement of inductance (L), capacitance (C), resistance (R), conductance (G), and dissipation factor (D) at a test frequency of 120Hz (100Hz optional). Measurement accuracy and versatility satisfies most demanding engineering or scientific applications.

To operate, merely push the button for the desired function, manually turn the knob to the desired range, and connect the unknown. KELVIN KLIPS® test leads are included, thus ensuring true four-terminal connections. The position of the range switch, used in conjunction with the desired function button and front panel range scale, indicate the unit of measurement being displayed by the 3-1/2 digit LED readout.

Excellent reliability of the Model 254 is assured through use of solid state devices and etched circuit board construction. Its small size is ideal for use on benchtops where work space may be at a premium. The carrying handle tilts the unit to a convenient viewing angle. Rear panel brackets provide line cord storage and enable it to be operated in a vertical position.



## .2 SPECIFICATIONS

|                         |                                            | Ranges                                                                             |       |                                                           |          |       |        |                                                           |                                                           |
|-------------------------|--------------------------------------------|------------------------------------------------------------------------------------|-------|-----------------------------------------------------------|----------|-------|--------|-----------------------------------------------------------|-----------------------------------------------------------|
|                         |                                            | 0                                                                                  | 1     | 2                                                         | 3        | 4     | 5      | 6                                                         | 7                                                         |
| Digit Count Values      | L <sub>s</sub>                             | 2000 μH                                                                            | 20 mH | 200 mH                                                    | 2000 mH  | 20 H  | 200 H  | 2000 H                                                    | 2000 H                                                    |
|                         | C <sub>p</sub>                             | 2 nF                                                                               | 20 nF | 200 nF                                                    | 2 μF     | 20 μF | 200 μF | 2000 μF                                                   | 20 mF                                                     |
|                         | R <sub>s</sub>                             | 2 Ω                                                                                | 20 Ω  | 200 Ω                                                     | 2000 Ω   | 20 kΩ | 200 kΩ | 2000 kΩ                                                   | 2000 kΩ                                                   |
|                         | G <sub>p</sub>                             | 2 μS                                                                               | 20 μS | 200 μS                                                    | 2000 μS  | 20 mS | 200 mS | 2000 mS                                                   | 20 S                                                      |
|                         | D                                          | 1 999                                                                              |       |                                                           |          |       |        |                                                           |                                                           |
| Accuracy (15°C to 35°C) | L <sub>s</sub>                             | ±[0.25% + (1 + 0.002R <sub>s</sub> <sup>*</sup> ) digits]**                        |       | ±[0.25% + (1 + 0.001R <sub>s</sub> <sup>*</sup> ) digits] |          |       |        | ±[0.25% + (1 + 0.002R <sub>s</sub> <sup>*</sup> ) digits] | ±[0.25% + (1 + 0.002R <sub>s</sub> <sup>*</sup> ) digits] |
|                         | C <sub>p</sub>                             | ±[0.25% + (1 + 0.002G <sub>p</sub> <sup>*</sup> ) digits]**                        |       | ±[0.25% + (1 + 0.001G <sub>p</sub> <sup>*</sup> ) digits] |          |       |        | ±[0.25% + (1 + 0.002G <sub>p</sub> <sup>*</sup> ) digits] | ±[0.5% + (1 + 0.004G <sub>p</sub> <sup>*</sup> ) digits]  |
|                         | R <sub>s</sub>                             | ±[0.25% + (1 + 0.002L <sub>s</sub> <sup>*</sup> ) digits]                          |       | ±[0.25% + (1 + 0.001L <sub>s</sub> <sup>*</sup> ) digits] |          |       |        | ±[0.25% + (1 + 0.002L <sub>s</sub> <sup>*</sup> ) digits] | ±[0.25% + (1 + 0.002L <sub>s</sub> <sup>*</sup> ) digits] |
|                         | G <sub>p</sub>                             | ±[0.25% + (1 + 0.002C <sub>p</sub> <sup>*</sup> ) digits]                          |       | ±[0.25% + (1 + 0.001C <sub>p</sub> <sup>*</sup> ) digits] |          |       |        | ±[0.25% + (1 + 0.002C <sub>p</sub> <sup>*</sup> ) digits] | ±[0.5% + (1 + 0.004C <sub>p</sub> <sup>*</sup> ) digits]  |
|                         | D                                          | ±[1% + 0.002] for L or C ≥ 200 counts<br>±[2% + 0.010] for L or C 50 to 199 counts |       |                                                           |          |       |        |                                                           | ±(2% + 0.010)                                             |
| Test Signal             | Voltage<br>C <sub>p</sub> , G <sub>p</sub> | 1.0 VRMS                                                                           |       |                                                           | 0.1 VRMS |       |        |                                                           | 0.01 VRMS                                                 |
|                         | Current<br>L <sub>s</sub> , R <sub>s</sub> | 100 mA                                                                             | 10 mA | 1 mA                                                      | 100 μA   | 10 μA |        | 1 μA                                                      |                                                           |

\*Digit count, same range. (Must be less than 2000.)

\*\*After correction for test lead zero reading.

0°C to 15°C and 35°C to 50°C: add 0.1 (rated accuracy)/°C.

Table 1-1. Model 254 Specifications

Test Frequency: 120Hz  $\pm 1\%$  (100Hz optional).

Unknown Excitation: The 120Hz voltage ( $V_x$ ) and current ( $I_x$ ) levels listed in Table 1-1 are held constant by an internal amplitude control circuit.

Measurement Rate: Four per second; one second is required for first reading after connecting unknown to terminals.

Measurement Display: 3-1/2 digit LED with decimal point. Blanked for overload conditions.

Unit Display: Unit of measurement being displayed by the LED readout is indicated by front panel LED lamps used in conjunction with the desired function button and the front panel range switch.

External Bias: Rear panel terminals are provided for connection of external supply. 0V to 50VDC, 0.1A maximum. (Read Section 2.2.6 before using external bias.)

Static Charge Protection: Diode and resistor discharge network.



Connection to Unknown: Four-terminal, shielded, connections are provided by the KELVIN KLIPS® cable assembly (ESI Part Number 43072) supplied with the Model 254.

Outputs: Analog signals of 1V per 1,000 counts, 1kΩ source resistance is available at rear panel. L, C, R, or G, with simultaneous output of D for L or C.

Power Consumption: 4 watts typical.

Power Requirements: 100 to 125V or 200 to 250V, 50/60Hz.

Fuse: 1/16A, 250VAC, Type MDL Slo-Blo.

Size: Height (with feet) - 100mm (4 in.)  
Width - 260mm (10 in.)  
Depth (overall) - 370mm (14.6 in.)

Weight: 3.2kg (7 lb).

Accessories supplied with Model 254:

|                                   |              |
|-----------------------------------|--------------|
| KELVIN KLIPS® Four-Terminal Clips | ESI Part No. |
| Instruction Manual                | 43072        |
|                                   | 43762        |

Options Available:

|                                            |              |
|--------------------------------------------|--------------|
|                                            | ESI Part No. |
| Model 1412B Universal Limits Comparator    | 31412B       |
| Sorting Fixture Model 2001 (low frequency) | 32001        |
| Cable Assembly (for Model 2001 connection) | 43586        |
| Front Panel Dust Cover                     | 43374        |



## SECTION 2

# OPERATION

### 2.1 CONTROLS AND CONNECTORS

#### 2.1.1 Front Panel

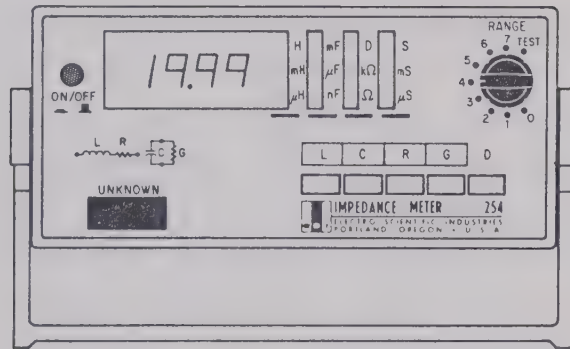


Figure 2-1. Model 254 Front Panel

1. ON/OFF Switch -- A push-on, push-off switch for applying and removing power from the instrument.
2. UNKNOWN Connector -- Terminals designed to be used with KELVIN KLIPS® test leads (ESI Part No. 43072), provided with Model 254, to provide a true four-terminal connection to the unknown or test fixture.
3. L, R, C, and G Pushbuttons -- Function pushbuttons select the type of meter circuit that will measure series inductance (L) and resistance (R) or parallel capacitance (C) and conductance (G).



D Pushbutton -- The push-to-read D (dissipation factor) pushbutton displays the D of a capacitor or inductor when the C or L function is selected.

Range Switch -- Selects the decimal multiplier and units of measurement for the meter circuit being used. For maximum accuracy, use the range that gives the highest digital count, unless the unknown is voltage or current sensitive (see Table 1-1).

Display -- A 3-1/2 digit readout for all functions.

Units Indicators -- Front panel LED lamps indicate the units of measurement. The basic multipliers and units are: H (henrys), mH (millihenrys),  $\mu$ H (microhenrys), mF (millifarad),  $\mu$ F (microfarad), nF (nanofarad), k $\Omega$  (kilohms),  $\Omega$  (ohms), S (siemens), mS (millisiemens),  $\mu$ S (microsiemens), and D (dissipation factor).

Tiltstand Handle -- Aids portability; tilts instrument for easier viewing of the LED display.



## 2.1.2 Rear Panel

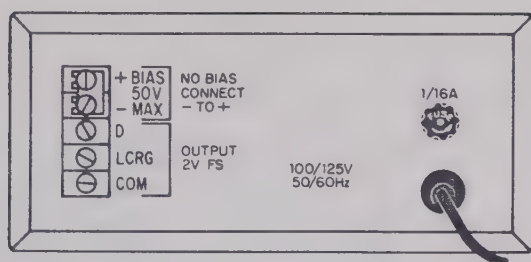


Figure 2-2. Model 254 Rear Panel

1. Bias Terminals -- Allows application of a  $0\text{V}$  to  $50\text{VDC}$ ,  $0.1\text{A}$  maximum bias to the capacitor being measured. (The shorting bar must be in place when not using bias feature.) See Section 2.3.6 before using external bias.
2. Output Terminals -- Provides two analog signals proportional to the function selected (L, R, C, or G) and D (for L and C). These terminals can be used with external DVM's (for increased full scale readings or resolution capability), with chart recorders, or with limits comparators, such as the ESI Model 1412B.
3. Fuse -- A  $1/16\text{A}$ ,  $250\text{V}$ , type MDL Slo-Blo is required.



## 2 OPERATING PROCEDURE

### 2.1 Power Requirements

Before turning the instrument ON, make sure the instrument is set to the proper line voltage. The Model 254 contains an internal slide switch to select the nominal line voltage (see Figure 2-3). In its up position, the switch selects 100 to 125VAC, 50/60Hz operation. In the down position it selects 200 to 250VAC, 50/60Hz operation.

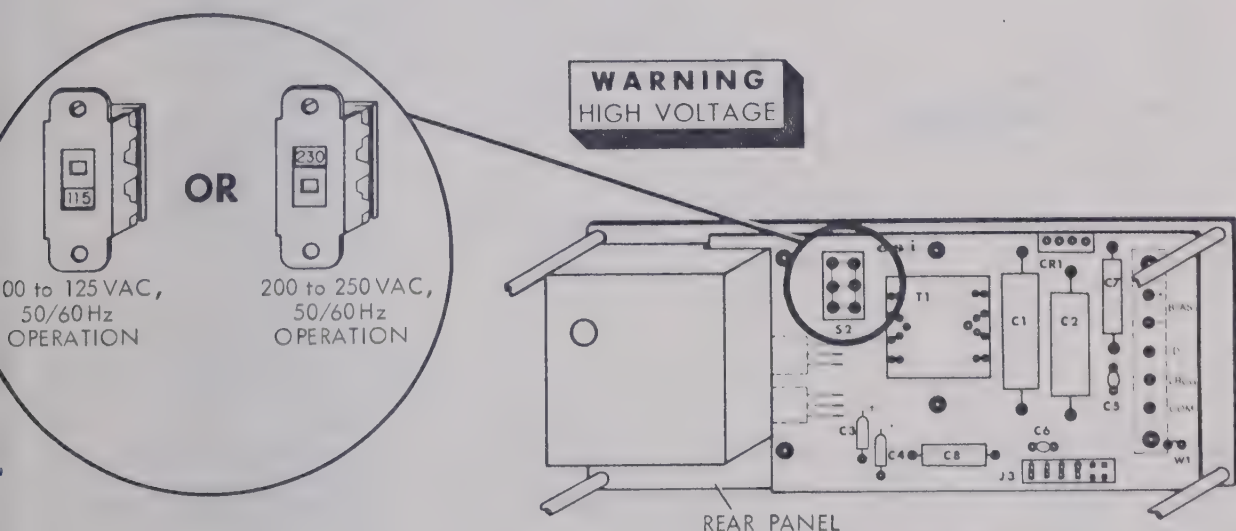


Figure 2-3. Line Voltage Switch

Because of differing power requirements all instruments shipped outside the United States are without a power cord connector. When placing a connector on the power cord, care must be taken to assure the wires are connected properly. The green or green with yellow stripe wire is always connected to earth ground. The white or light blue wire is connected to the neutral side of the power line. And, the black or brown wire is connected to the high side of the power line.



| CONDUCTOR         | COLOR | ALTERNATE COLOR |
|-------------------|-------|-----------------|
| Ungrounded Line   | Black | Brown           |
| Neutral Grounding | White | Light Blue      |
| Earth Grounding   | Green | Green-Yellow    |

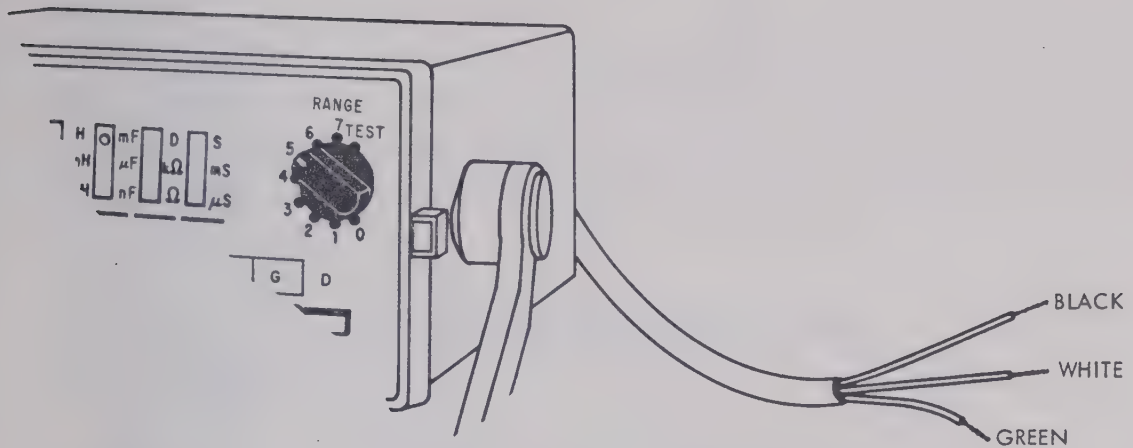


Figure 2-4. Power Cord

### 2.2.2 Applying Power

The push-on, push-off ON/OFF button in its depressed position applies power to the measurement circuitry. When power is applied, the LED display lights and reads zero when in C and G modes or the display is blank with the decimal point lit in the L and R modes.



## 2.3 Connection to Unknowns

The KELVIN KLIP® test lead set (ESI Part No. 43072) is plugged into the 254's front panel UNKNOWN connector. The test leads connector cover is spring-locking and should be squeezed together before setting or removing.

The test leads provide a shielded, four-terminal connection to the unknown (see Figure 2-5a). The clip with the red hinge-spool provides the HI DRIVE and HI SENSE connections to the unknown and the clip with the black hinge-spool make the LO DRIVE and LO SENSE connections.

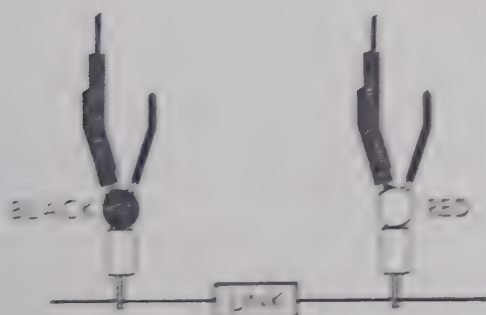
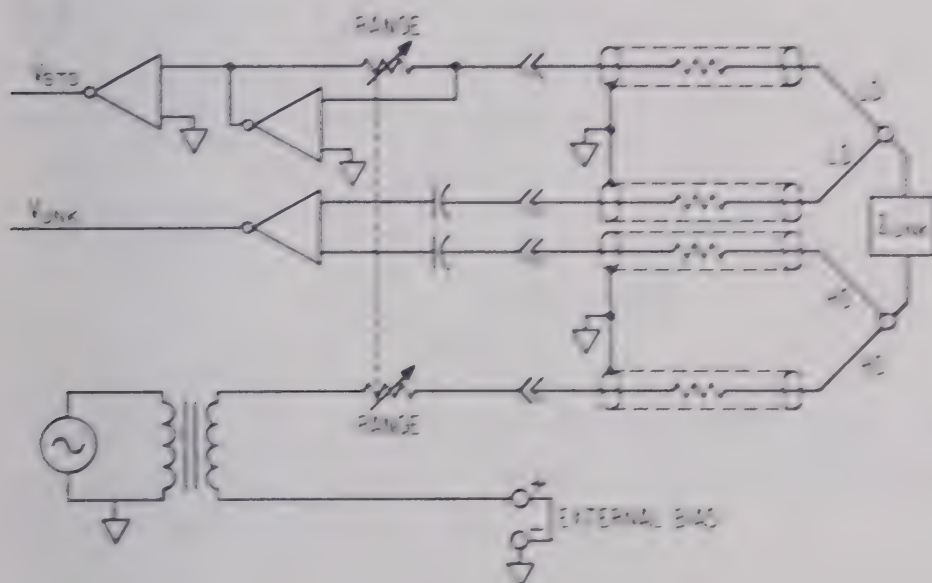
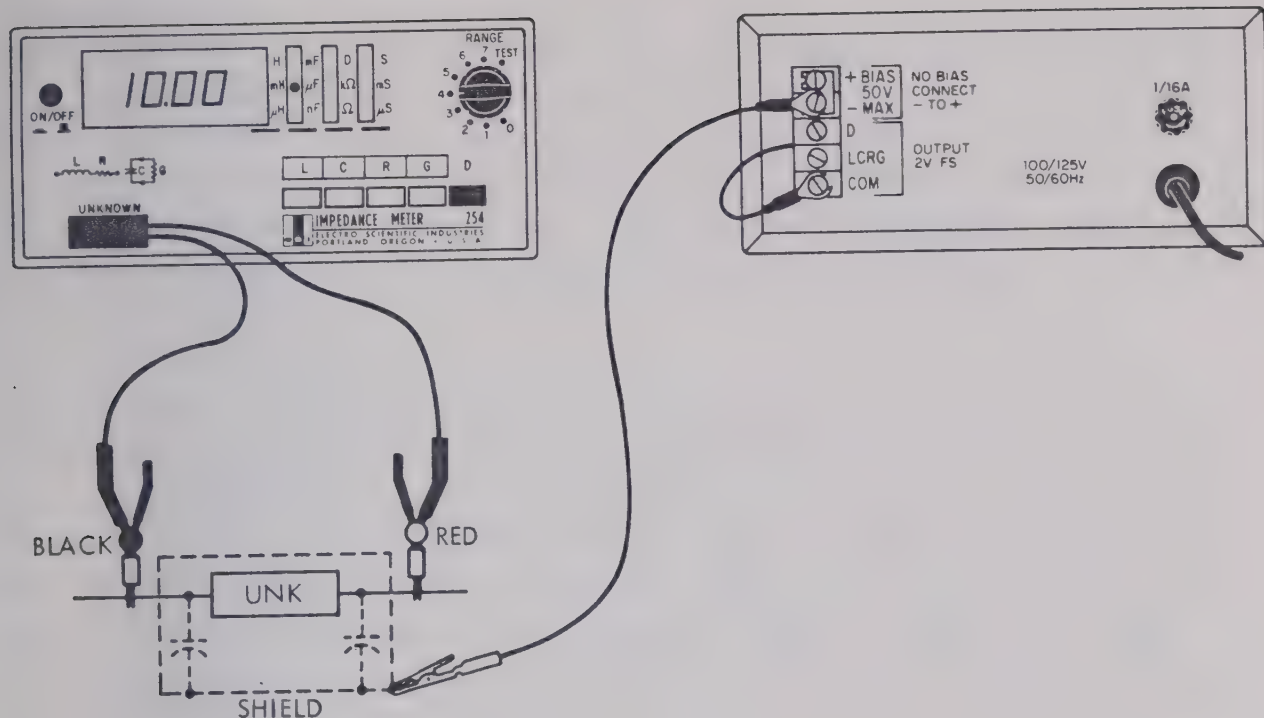


Figure 2-5a.





For connection to three terminal unknowns (the third connection is to ground), a ground wire must be added to the test lead set. This wire is connected as in Figure 2-5b.



### 2.2.3.1 Test Fixture Compensation

The Model 254 uses a 3.3pF capacitor (C6 in Figure 2-6) to compensate for the capacitance of the test leads. If the 254 is used with a test fixture, the larger capacitance of the fixture must be compensated for. There are two methods for compensating this larger capacitance. The first method is to make a zero capacitance measurement with the test fixture connected. This reading is mentally subtracted from all other measurements.

The second method for compensating the larger capacitance is to change the value of C6 from 3.3pF and to add an external trim capacitor. The external trim capacitor is connected in parallel with the unknown and should be of such a value that the test fixture capacitance can be trimmed to zero. Typically, the maximum value of this trim capacitor is 15pF. The trim capacitor can either be added to the test cable, between terminals 1 and 3 of the connector as shown in Figure 2-6, or it can be added to the test fixture.

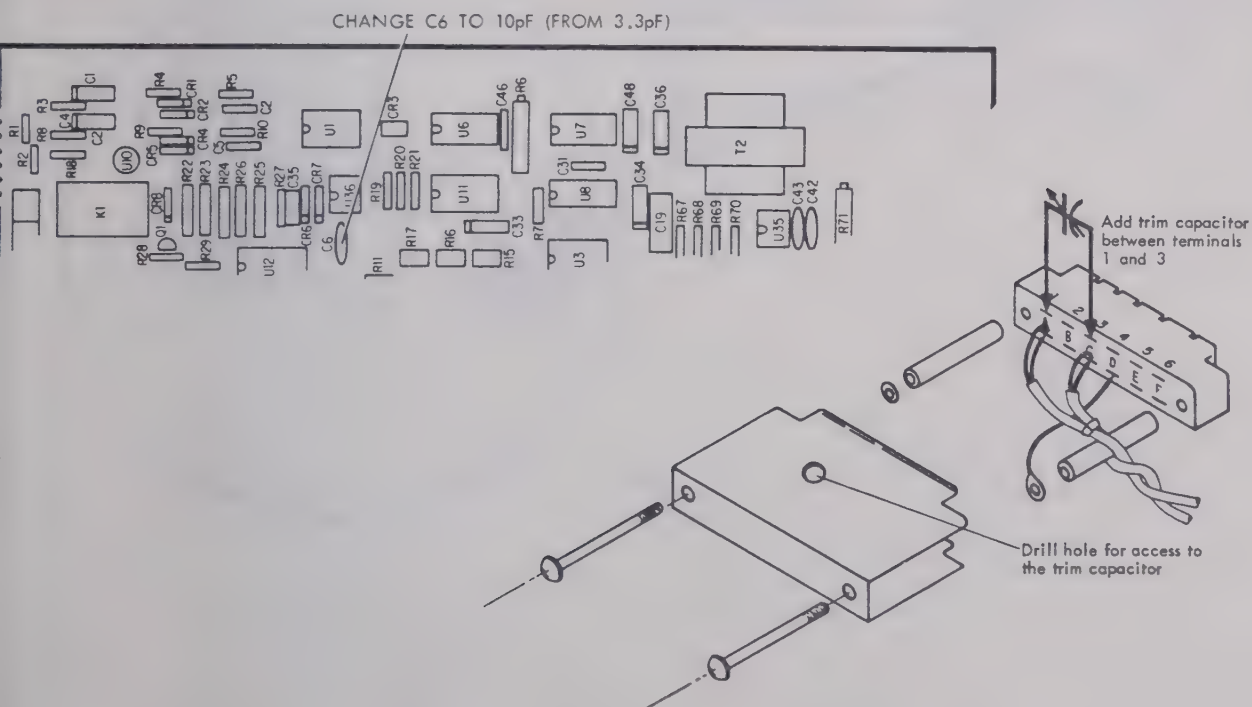


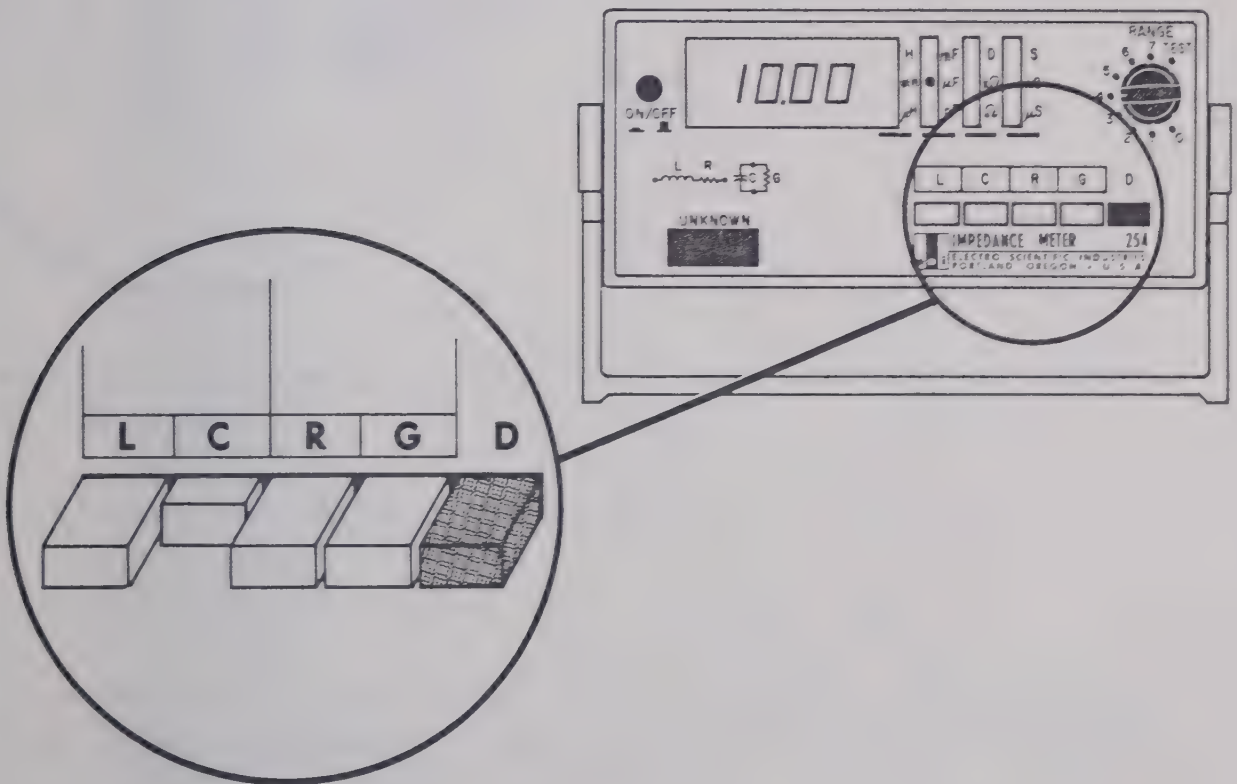
Figure 2-6. Test Fixture Compensation



## 2.2.4 Function Selection

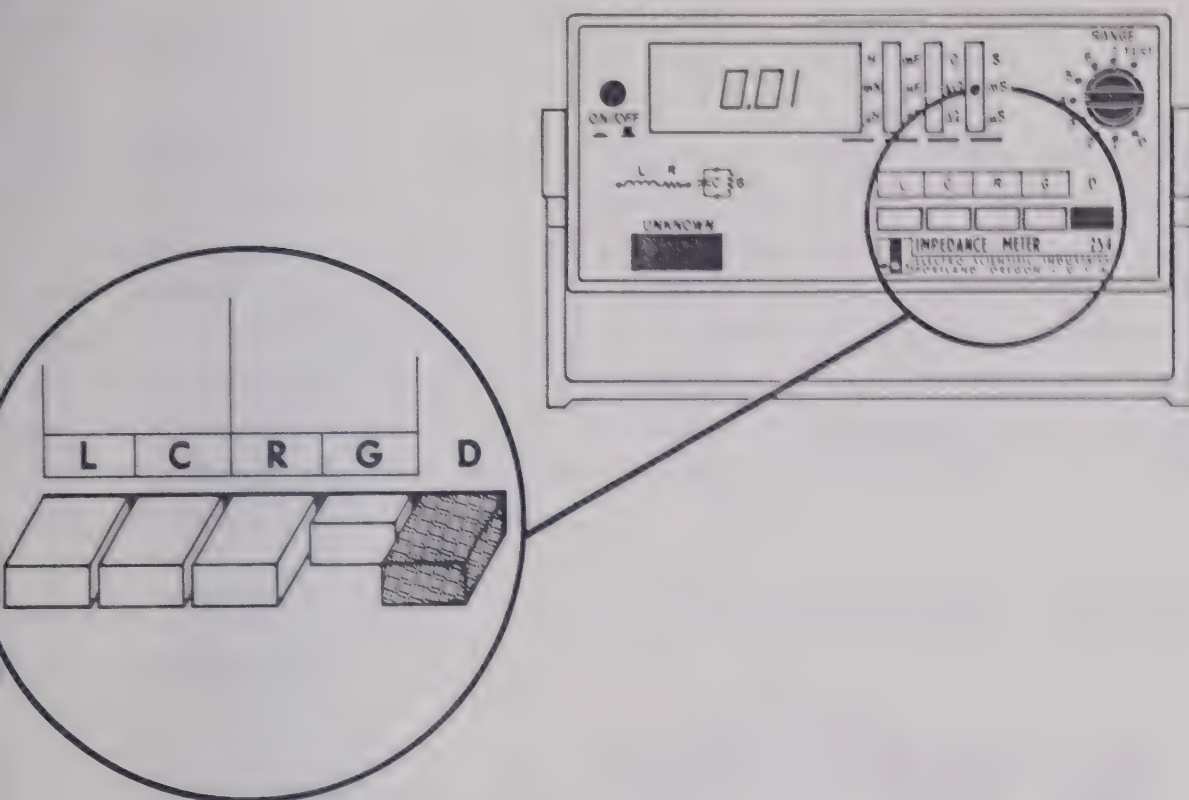
Model 254 is designed to measure series inductance (L), parallel capacitance (C), series resistance (R), parallel conductance (G), and dissipation factor (D) of inductance and capacitance. One of these measurement modes is selected by depressing the proper front panel button. (If all buttons are in their out position, the instrument reverts to the inductance measurement mode.)

Example: Select the capacitance measurement function. (Depress the C pushbutton.)





Example: Select the conductance measurement function. (Depress the G button.)



a negative sign appears on the display when measuring an unknown, possible causes are:

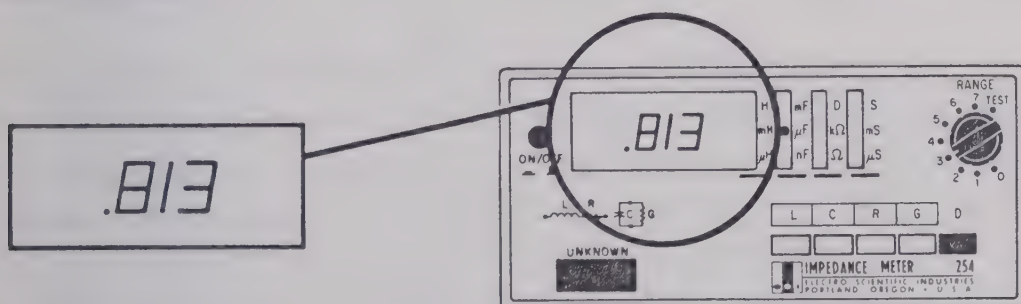
- "C" button has been pushed when measuring an inductor.
- "L" button has been pushed when measuring a capacitor.
- The unknown is more capacitive (or inductive) than suspected. For example, an inductor that resonates below 1kHz will measure as though it were a capacitor.
- A diode requires bias voltage (a negative reading may appear if bias voltage is not applied).



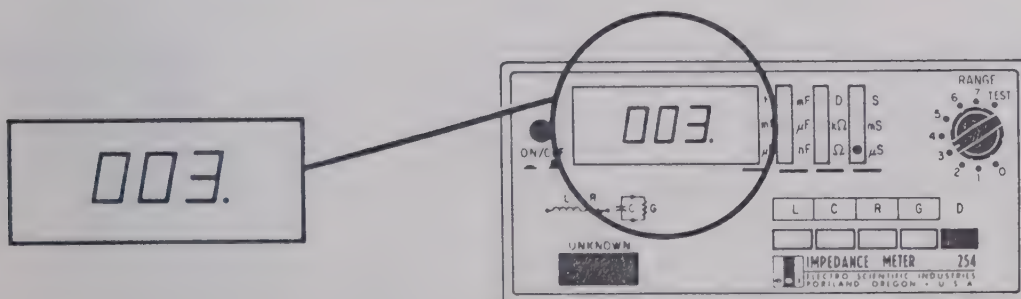
To measure the dissipation factor (D) of a capacitor or inductor, push and hold the D button while the C or L function is selected. (The display will blank if D is pushed, while the unit is in R or G mode and the unknown is resistive.)

When measuring the conductance (G) of a capacitor or the resistance (R) of an inductor, the R or G reading may be quite small. In trying to acquire more resolution by moving the range switch to the next lower range, the display will usually blank, indicating overload. Blanking occurs because the instrument is still monitoring the reactive component (L or C) in addition to measuring and displaying the loss component (R or G). In moving to the next lower range, the reactive component becomes too large for the lower range causing overload and a blanked display.

Example: While measuring a  $0.82\mu\text{F}$  capacitor using the  $2\mu\text{F}$  range, the 254 display reads:

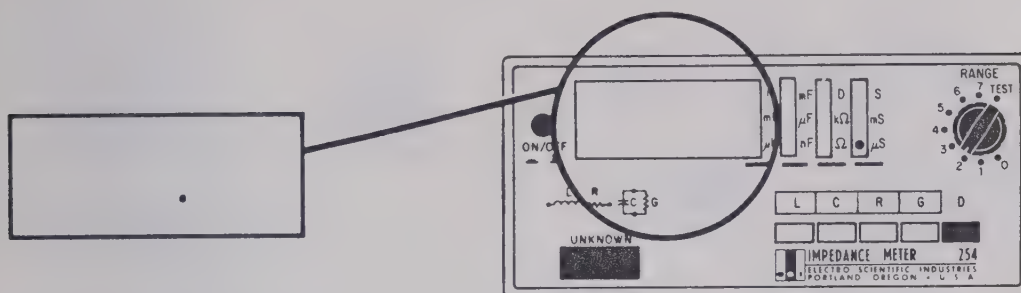


Switching to the conductance (G) mode, the display may read:





trying further to investigate this reading, you down range from the 2000  $\mu$ S range to the 200  $\mu$ S range. The display blanks:



the display blanks because, while ranging from 20mS to 2000  $\mu$ S, the capacitance range changed from 2  $\mu$ F to 200nF. Since 0.82  $\mu$ F is too large to measure on the 200nF range, an overload occurs and the display blanks.

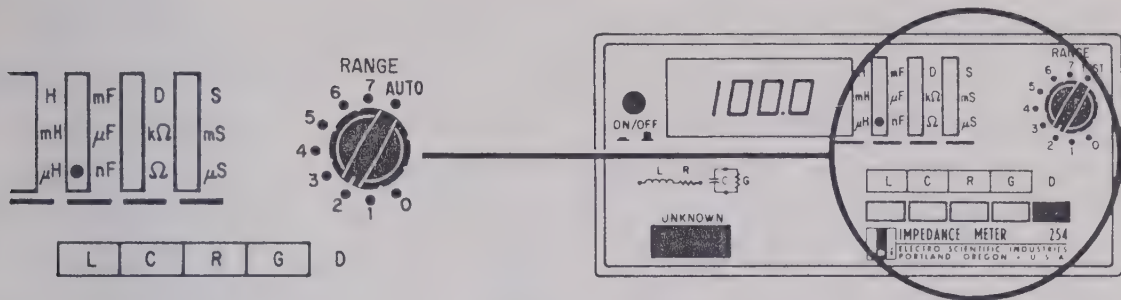
## 2.5 Range Selection

Measurement ranges are selected by a nine-position rotary switch. See figure 2-7 for full-scale range values. For maximum display resolution and accuracy, select the range that gives the largest on-scale reading. Front panel LEDs indicate the readout units (i.e.  $\mu$ H, H, H, etc.). If either the reactive or resistive value of the unknown exceeds the range selected, the display will blank.

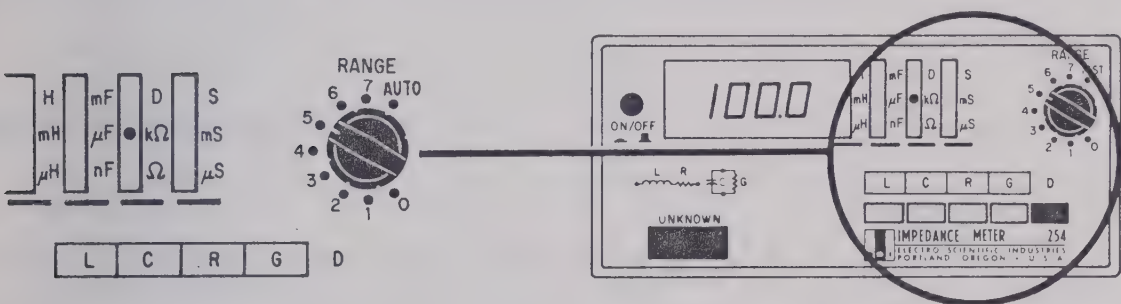
|        | Ranges       |             |              |               |               |                |                 |                 |
|--------|--------------|-------------|--------------|---------------|---------------|----------------|-----------------|-----------------|
|        | 0            | 1           | 2            | 3             | 4             | 5              | 6               | 7               |
| Values |              |             |              |               |               |                |                 |                 |
| $L_s$  | 2000 $\mu$ H | 20 mH       | 200 mH       | 2000 mH       | 20 H          | 200 H          | 2000 H          | 2000 H          |
| $C_p$  | 2 nF         | 20 nF       | 200 nF       | 2 $\mu$ F     | 20 $\mu$ F    | 200 $\mu$ F    | 2000 $\mu$ F    | 20 mF           |
| $R_s$  | 2 $\Omega$   | 20 $\Omega$ | 200 $\Omega$ | 2000 $\Omega$ | 20 k $\Omega$ | 200 k $\Omega$ | 2000 k $\Omega$ | 2000 k $\Omega$ |
| $G_p$  | 2 $\mu$ S    | 20 $\mu$ S  | 200 $\mu$ S  | 2000 $\mu$ S  | 20 mS         | 200 mS         | 2000 mS         | 20 S            |
| D      | 1.999        |             |              |               |               |                |                 |                 |



Example: Set the instrument to measure 100nF capacitors.

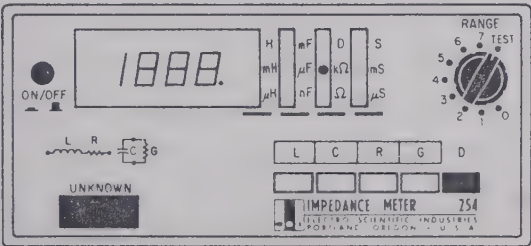


Example: Set the instrument to measure 100kΩ resistors.



If the value of a component is not known, set the instrument to its highest range before connecting the test leads. Step the instrument down one range at a time until the range with the highest resolution is reached. If the display is blank after the component is connected, the value of the component is too large to measure directly, see Section 2.3 for alternate measurement techniques.

Display TEST. This position of the range switch is used to test all segments of the LED display. When the range switch is placed in the "TEST" position the display will indicate:





## .6 Summary of Operation

Press the appropriate function button (L, C, R, or G) and connect the VIN KLIPS® to the unknown. For maximum accuracy, select the range that gives the largest on-scale reading. The measurement is displayed every one second or less. Repetitive measurements are made at the rate of four per second. The position of the range switch indicates the readout units (i.e.  $\mu\text{H}$ ,  $\text{mH}$ ,  $\text{H}$ , etc.). If the value of the unknown exceeds the range selected, the display will remain blanked. To measure the dissipation factor of a capacitor or inductor, push and hold the D button while the C or L function is selected.

## MEASUREMENT TECHNIQUES

### .1 Resistance Measurements at 120Hz (or 100Hz)

When using the resistance function, the maximum measurement is 1999k $\Omega$ . For measurements from 1999k $\Omega$  to 1000M $\Omega$ , use the G (conductance) function where  $G=1/R$  or  $R=1/G$ . Measurement accuracy is determined by  $\pm 0.25\% + 1 \text{ digit}$  where 1 digit will be  $\pm 100\%$  at 1000M $\Omega$ ,  $\pm 10\%$  at 100M $\Omega$ , and  $\pm 1\%$  at 10M $\Omega$ .

High-value, bobbin-type, wire-wound resistors have shunt capacitance which may affect measurements by appearing as " $-L_s$ ". This causes some difference between AC and DC resistance measurement values.

The resistive component ( $R_s$ ) of inductors and transformers, when measured at 120Hz, will differ from the DC winding resistance. If the core material is air or low loss (e.g. powdered permalloy), the AC and DC values will be nearly equal. For laminated magnetic cores, the AC resistance will be greater than the winding resistance (sometimes much greater). This is caused by the core losses which change both with frequency and test current level.



2.3.2 Capacitance Measurements

Shielded devices. For shielded devices, the shield should be connected to the rear panel -Bias terminal to provide proper guarding.

Most two- and four-terminal cables or sorting fixtures are not guarded immediately adjacent to where the unknown capacitor is connected, and a zero capacitance reading can change by a few picofarads whenever the ends of the cable or fixture terminals are physically moved. Always maintain the physical orientation of the leads or terminals after checking for zero capacitance. Subtract zero-capacitance reading from the capacitance reading for the unknown.

Equivalent Series Resistance (ESR). To measure series resistance of capacitors, use the Rs function. Series resistance will be displayed on the front panel.

Series Capacitance. The Ls function can be used to measure series capacitance. (The capacitor is measured with a constant current rather than a constant voltage.) A negative reading will be shown, and the following equation must be used to convert the "-Ls" readings to the "Cs" values:

$$Cs = \frac{1}{(2\pi f)^2 (Ls)}$$

- Where: f = frequency in hertz  
Cs = series capacitance in farads  
Ls = series inductance in henrys (ignore sign)



dissipation factor (D). The D of large value electrolytic capacitors can be determined using the Ls and Rs functions (using the same range). The following equation converts the Rs and Ls, in counts (ignore the sign and decimal point), to D values:

$$D = 1.59 \times \left( \frac{Rs}{Ls} \right) \text{ for } 100\text{Hz and } 1\text{kHz operation}$$

$$D = 1.33 \times \left( \frac{Rs}{Ls} \right) \text{ for } 120\text{Hz operation}$$

where: D = dissipation factor  
 Rs = equivalent series resistance reading in counts  
 Ls = series inductance in counts

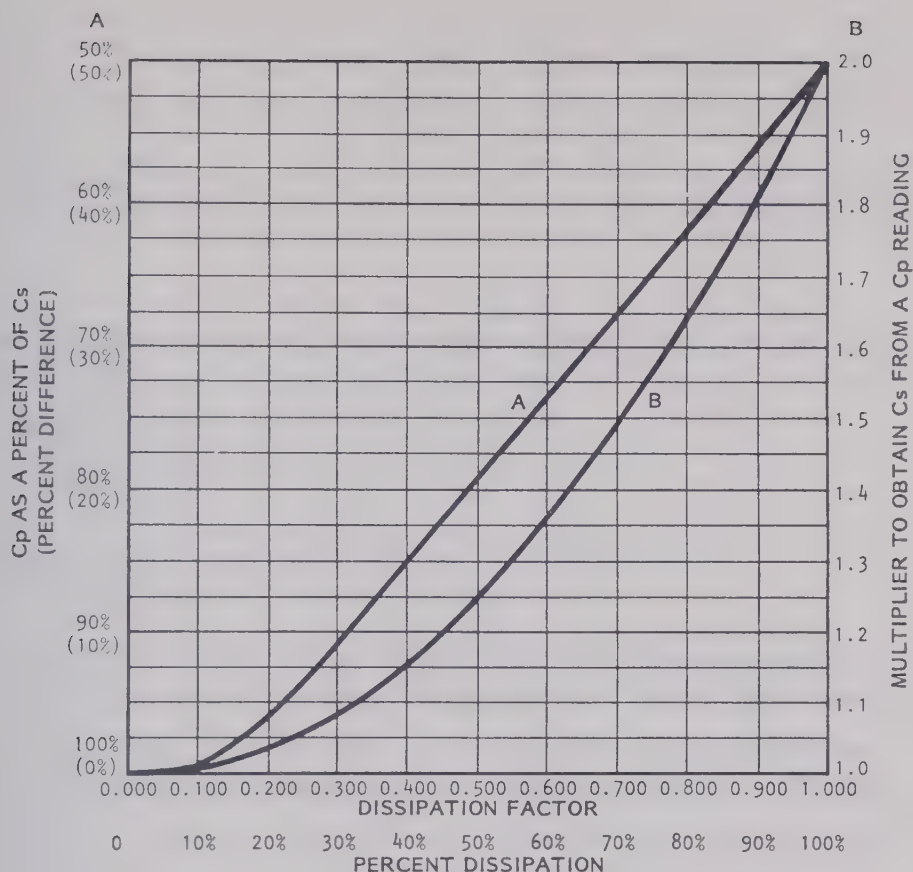
Parallel Capacitance Measurement. The relation between parallel and series capacitance measurements is:

$$Cs = (1 + D^2) Cp \text{ where } D = Gp/2 fCp$$

The following graph illustrates the relation between Cs and Cp. The graph is used to obtain a Cs value for a capacitor by measuring the Cp and D values of the capacitor. To locate the Cs value, find the measured D value along the horizontal axis of the graph. (The D reading from the Model 254 will be a Dissipation Factor value not a Percent Deviation value.) Move up the graph to the B curve and read the corresponding value on the righthand vertical axis. Multiply the measured Cp value by this reading to obtain the desired Cs value.

The A curve on the graph is used with the lefthand vertical axis in the same manner as described above. The A curve and lefthand scale provide the Percent Difference between Cs and Cp.





### 2.3.3 Inductance Measurements

The 254 measures the total impedance connected to its terminals. Both the unknown inductor and its leads contribute to this impedance. The leads have some resistance and inductance which affect the value read from the meter.

In making high inductance measurements, avoid AC pickup and keep the stray capacitance to a minimum. To minimize both effects, keep hands as far as possible from the inductor being measured. Keep the leads as short and direct as possible. Take care to avoid coupling stray magnetic fields into the inductor.



For greatest accuracy on low inductance measurements, minimize the lead impedance. Closely spaced, twisted leads will reduce the inductance and pickup of stray fields. The KELVIN KLIPS® Cable Assembly will add about  $0.5\mu\text{H}$  to  $L_s$  and  $0\text{m}\Omega$  to  $R_s$ . Short the test leads together and subtract the reading from the unknown inductance measured.

Measuring leakage inductance of transformer windings is an easy task for the Model 254 since there are no "false nulls" as found in manually-balanced bridges.

### 3.4 Determining Quality Factor (Q) of Inductors

To determine the Q of inductors, push the D button, record the D reading and calculate Q from the equation  $Q=1/D$ . This procedure works well for  $Q>0.5$  (or  $D<2$ ). For  $Q<0.5$ , measure the inductance of the unknown and record the readout display in digits only. With the RANGE switch in the same position, press the R button and note the readout display in digits, only. Do not record the decimal point or range multiplier for  $L_s$  or  $R_s$ ; they are not required. Turn to Figure 2-8 for the D-Q nomograph. Use a straightedge to line up the  $L_s$  digits recorded (left-hand scale) with the  $R_s$  digits recorded (right-hand scale). Q is taken from the left-hand side of the center scale where the straightedge crosses. For example, with an  $L_s$  digital display of "300" and an  $R_s$  digital display of "600", Q is 0.4. Accuracy of Q is primarily limited by interpolation of the nomograph.



Although the nomograph provides a convenient way to approximate Q, it may be determined more accurately by the formula:

$$Q = 0.628 \times \left( \frac{L_s}{R_s} \right) \text{ for } 100\text{Hz and } 1\text{kHz operation}$$

$$Q = 0.754 \times \left( \frac{L_s}{R_s} \right) \text{ for } 120\text{Hz operation}$$

Where: Q = Quality Factor

R<sub>s</sub> = equivalent series resistance reading in counts

L<sub>s</sub> = series inductance in counts

See Table 1-1 for accuracy of L<sub>s</sub> and R<sub>s</sub> measurements.

### 2.3.5 Determining Dissipation Factor (D) of Capacitors Using Nomograph

Model 254 will measure dissipation factor up to 1.999. For D values greater than 2 the nomograph should be used. Measure the capacitance of the unknown and record the readout display in digits only; do not record the decimal point. With the RANGE switch left in the same position, push the G button and note the readout display in digits only; do not record the decimal point. Turn to Figure 2-8 for the D-Q nomograph. Use a straightedge to line up the C<sub>p</sub> digits recorded (left-hand scale) with the G<sub>p</sub> digits recorded (right-hand scale). D is taken from the right-hand side of the center scale where the straightedge crosses. For example, with a C<sub>p</sub> digital display of "200" and a G<sub>p</sub> digital display of "300", D is 2.3. Accuracy of D is primarily limited by interpolation of the nomograph.



dissipation factor may be determined more accurately by the formula:

$$D = 1.59 \times \left( \frac{G_p}{C_p} \right) \text{ for } 100\text{Hz and } 1\text{kHz operation}$$

$$D = 1.33 \times \left( \frac{G_p}{C_p} \right) \text{ for } 120\text{Hz operation}$$

where: D = Dissipation factor

Gp = parallel conductance reading in counts

Cp = parallel capacitance in counts

See Table 1-1 for accuracy of Cp and Gp measurements.

Electrolytic capacitors with high dissipation are usually unstable and the measured values may drift.



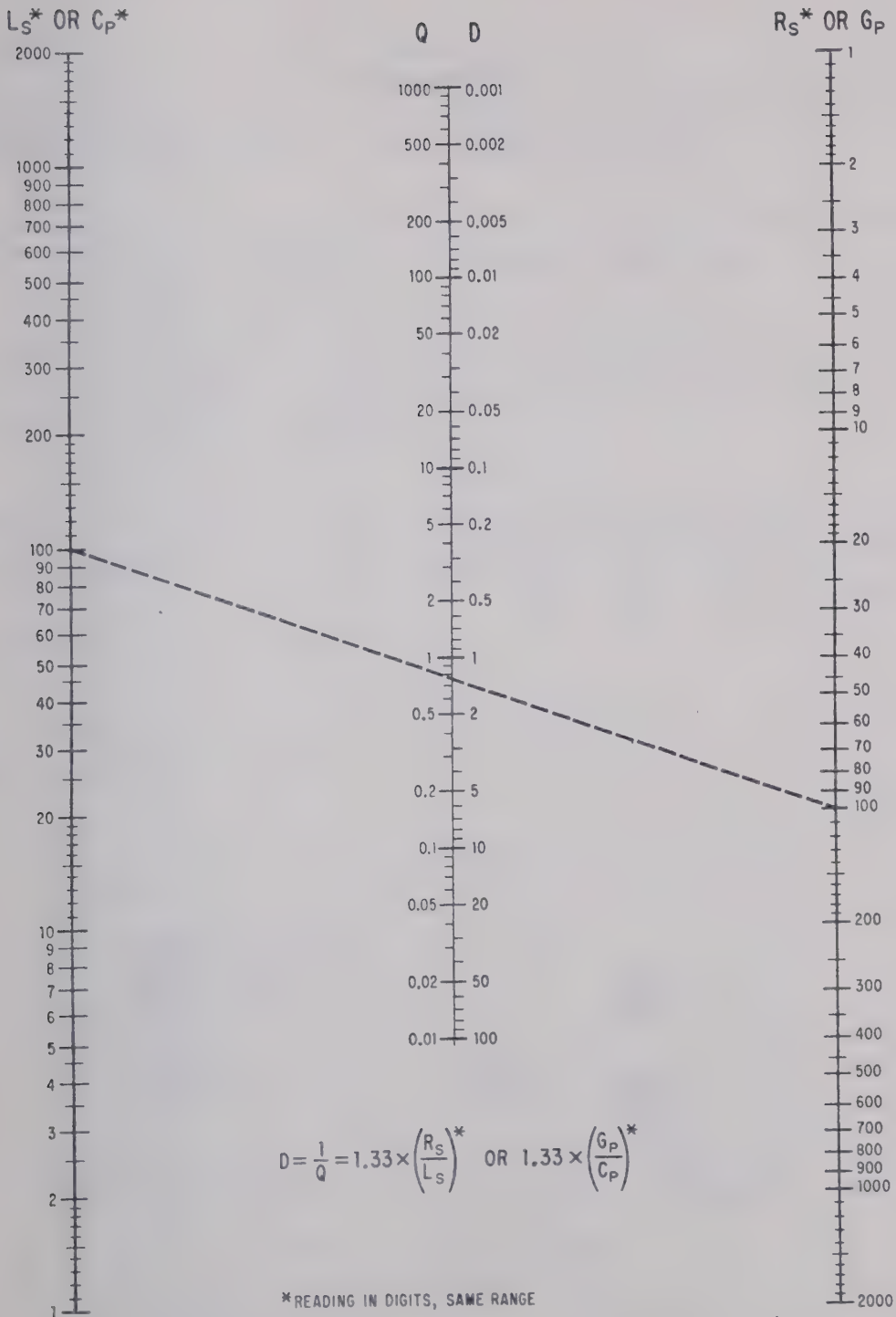


Figure 2-8. Model 254 D-Q Nomograph



## 2.6 Using the Bias Feature

### WARNING

TO AVOID PERSONAL INJURY FROM ELECTRICAL SHOCK OBSERVE SAFETY PROCEDURES AS NEEDED FOR THE BIAS VOLTAGE APPLIED.

A bias voltage is necessary or desirable when measuring the capacitance of diodes or of some electrolytic or tantalum capacitors.

There is a provision on the rear panel for connecting an external bias source of zero to 50VDC. Remove the shorting link between BIAS terminals when using this feature.

If the external bias supply is not a low AC impedance type, it should have a capacitor bypass of five times the range full-scale value connected across the bias terminals. The bias supply should be current limited to 0.1A maximum.

With no bias supply connected, the rear-panel + and - terminals must be strapped together.

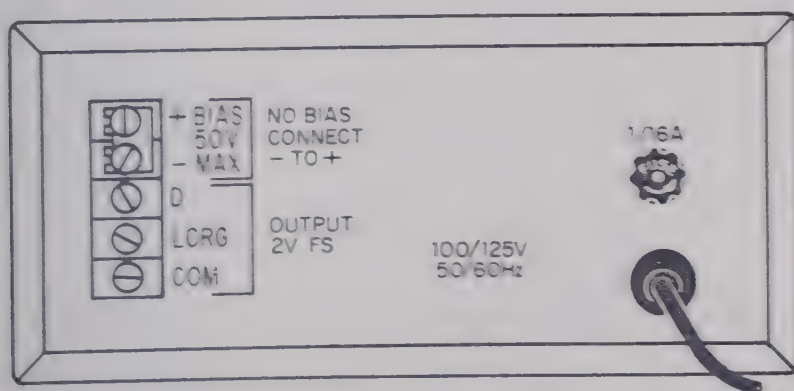


Figure 2-9. Rear Panel



2.3.7 Signal Output Terminals

Terminals are provided on the Model 254's rear panel for connecting external devices: digital voltmeters to increase full-scale resolution or simultaneous D reading; chart recorders to evaluate unknowns with changing impedances; limits comparators (ESI Model 1412B) for HI, LO, GO, and HI D component sorting.

The analog output signals are proportional to the function selected (L, C, R, or G) and D (for L and C only). Specifications for these signals are:

|                   |                           |
|-------------------|---------------------------|
| Scale Factor      | 1V per 1000 counts        |
| Source Resistance | 1000Ω                     |
| Accuracy          | ±(0.25% of reading + 1mV) |

2.3.8 Measuring Grounded Unknowns

The Model 254 is designed to measure ungrounded components. However, with a minor modification, it can be used to measure impedances that are connected directly or tightly coupled to earth ground.

This first procedure outlines the modification of all instruments with serial numbers 928999 and smaller.

1. Remove all instrument power.
2. Remove instrument cover by unscrewing the two cover screws and sliding the cover off.



TO AVOID PERSONAL INJURY FROM ELECTRIC SHOCK DO NOT REMOVE INSTRUMENT COVERS OR PERFORM ANY MAINTENANCE OTHER THAN DESCRIBED IN THIS MANUAL. INSTALLATION AND MAINTENANCE PROCEDURES DESCRIBED IN THIS MANUAL ARE TO BE PERFORMED BY QUALIFIED SERVICE PERSONNEL ONLY.



Locate the Power Supply Circuit Assembly, Part No. 53157.  
(Attached to the rear panel.)

Remove jumper wire W1 from this assembly (see Figure 2-10).

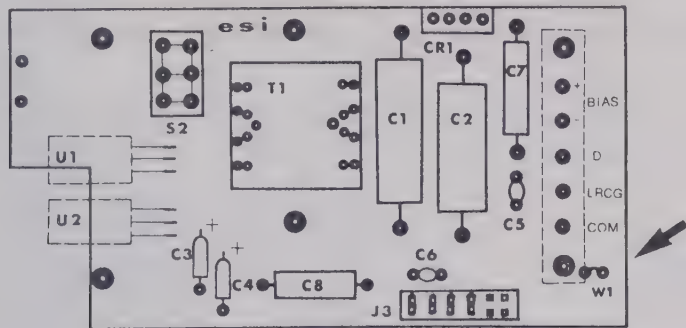


Figure 2-10. Power Supply Circuit Assembly

Locate the Range Switch on the front panel.

Unsolder and isolate the solder lug from the Range Switch making sure the black wire remains attached to the switch terminal (see Figure 2-11).

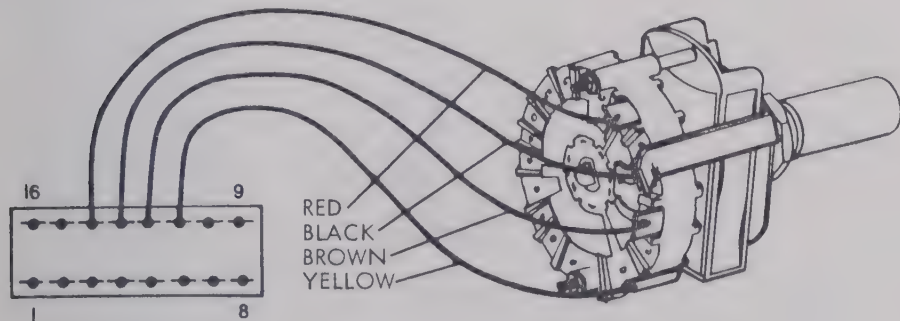


Figure 2-11.

Replace instrument cover.



The modification of instruments with Serial Numbers 929000 and greater is as follows:

1. Locate the connector strip on the rear panel (see Figure 2-12).
2. Remove and isolate the spade lug from the terminal marked COM.

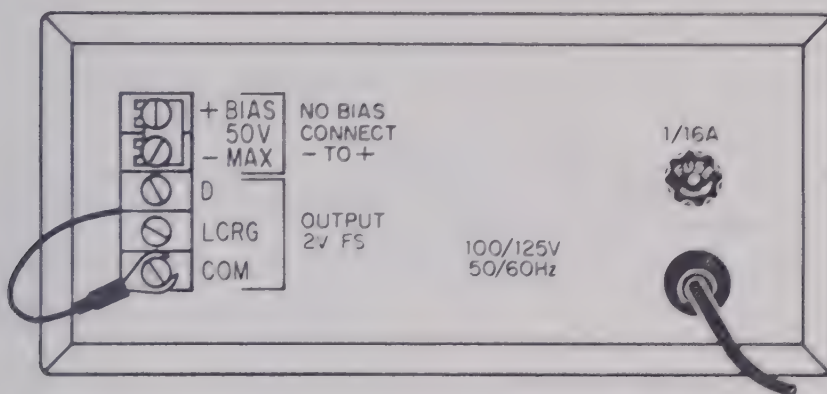


Figure 2-12.

To make measurements of grounded unknowns, connect the grounded side of the unknown to the KELVIN KLIPS® with the red insulating hinge-spool and the ungrounded end to the clip with the black spool (see Figure 2-13).

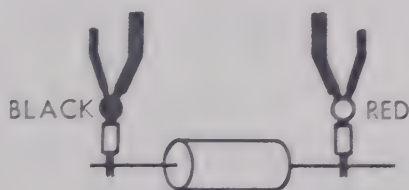


Figure 2-13.



small zero offset may become apparent during low value grounded capacitance measurements. This offset can be corrected by making a reading with the unknown connected only to the red clips and subtracting it from the final measured capacitance.

To return to normal ungrounded measurements reverse the above procedures.

### 3.9 Measuring Battery Impedance

Current producing capabilities of a battery can be determined by using the 254 to measure its impedance. Series resistance and series capacitance measurements can be made on batteries with voltages up to 20V. To measure series resistance:

1. Set the 254 to measure  $R_s$  and to the highest measurement range.
2. Remove the shorting bar from the + and - bias terminals. The bias terminals are located on the instrument's rear panel terminal strip.
3. Connect a 500 $\mu$ F (or larger) capacitor, whose working voltage is greater than the rated voltage of the battery, to the bias terminals (see Figure 2-14). Observe correct polarity when connecting the capacitor.
4. Connect the test leads with the red hinge-spool to the positive battery terminal and the lead with the black hinge-spool to the negative terminal (see Figure 2-14).



5. Move the range switch to the range with the highest resolution displayed (see Section 2.2.5) unless that range uses excessive test current for the size of battery being measured. See Table 1-1 for range test currents.

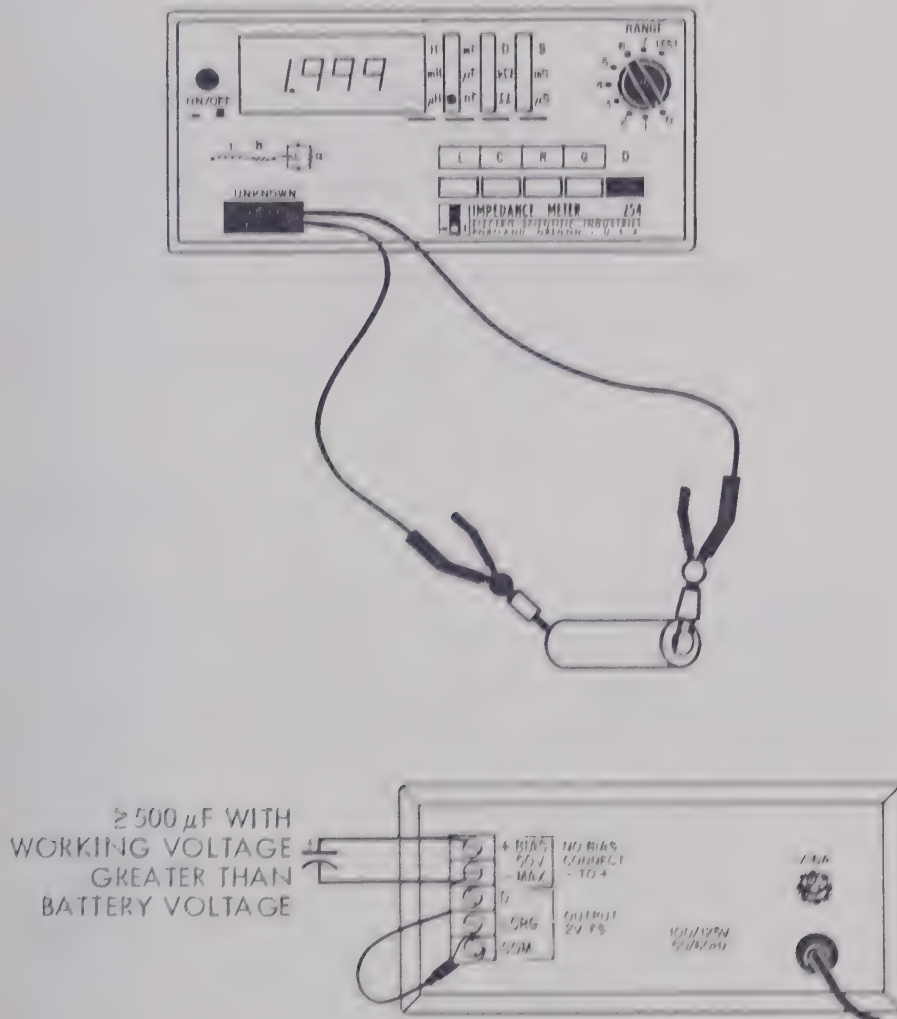


Figure 2-14. Measuring Battery Impedance.



The Ls function must be used to measure the series capacitance of a battery. Instrument set up is the same as for Rs measurements (Figure 2-14). A negative reading will be shown, and the following equation must be used to convert the "-Ls" reading to "+Cs" values:

$$Cs = \frac{1}{(2\pi f)^2 (-Ls)}$$

Where: f = frequency in hertz

Cs = series capacitance in farads

Ls = series inductance in henrys

Care must be taken so the measurement current level of the 254's internal source does not exceed the rating of the battery being tested. See Table 1-1 for range test currents.

### 2.3.10 Component Sorting

Model 254, when used with ESI Model 1412B Limits Comparator, sorts components according to percent deviation and dissipation factor, simultaneously. Component sorting can be manual or automatic; Model 1412B provides four contact closures for operating automatic component handling equipment.



Model 1412B front panel controls set upper and lower limits around a nominal value (L, R, C, or G), with either of two full scale ranges -- 10% or 100%. An upper limit for dissipation factor (D) is also set by a front panel control. Test results are shown by four front panel LEDs. They indicate:

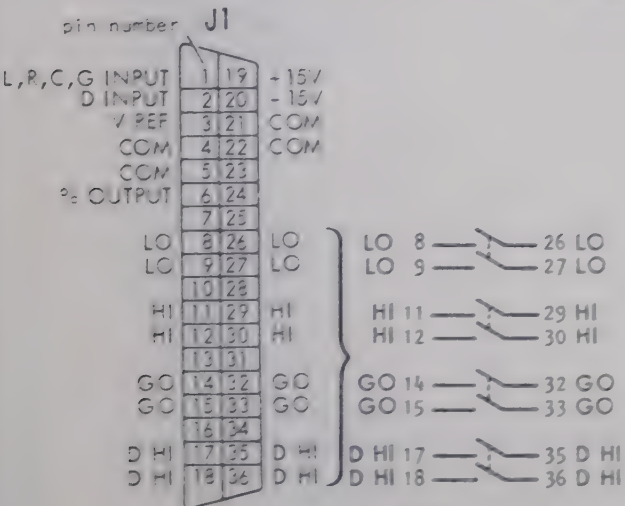
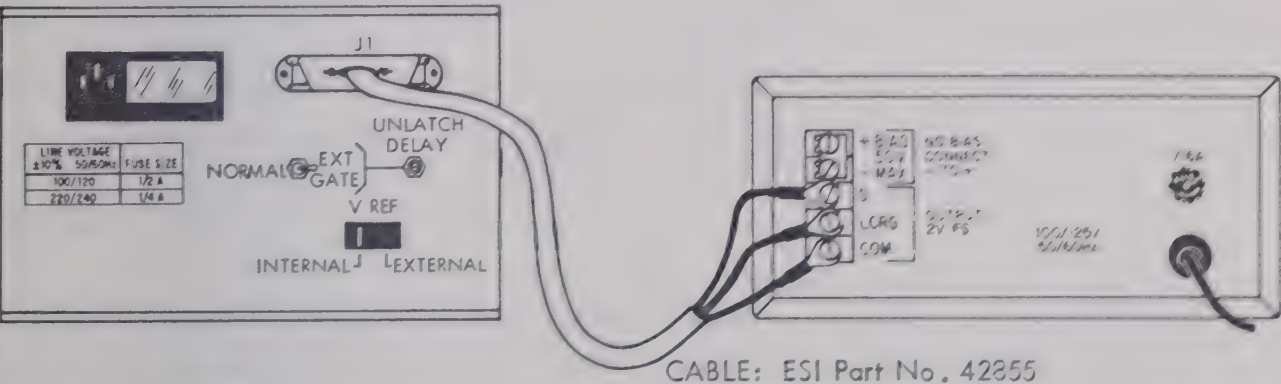
GO indicates value between - and + % limits and less than D limit.

LO indicates value less than - % limit.

HI indicates value greater than + % limit.

D HI indicates dissipation factor greater than limit.

Connect the 254 and 1412B as shown in Figure 2-15.



NOTE: For resistive unknowns connect the D lead to the COM terminal

Figure 2-15. Model 254 and Model 1412B Interconnection



ration

following instructions assume Model 254 and Model 1412B are connected and both are turned on.

Model 254 setup: (for capacitor sorting)

1. Push the C button on the Model 254 front panel.
2. Set the range switch to give maximum resolution on the display.

Model 1412B setup:

1. Set the rear panel V REF switch to INTERNAL.
2. Set NOMINAL VALUE switches to anticipated value.
3. Set LIMITS FULL SCALE toggle switches, and % LIMITS and D LIMIT dials to desired limits.

The measurement:

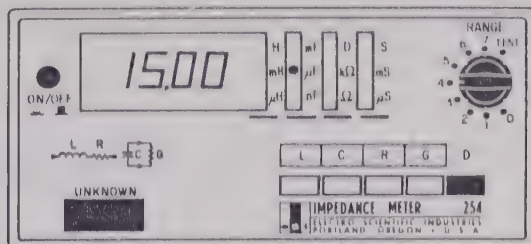
Connect unknown to the Model 254. If the unknown is within the set limits, the GO LED will light. If it is not within limits, the appropriate indicator will light.



Example: Sort  $15\mu\text{F}$  capacitors within  $+25\%$ ,  $-15\%$  limits with a maximum dissipation limit of  $0.0250$ . Instrument set up is as follows:

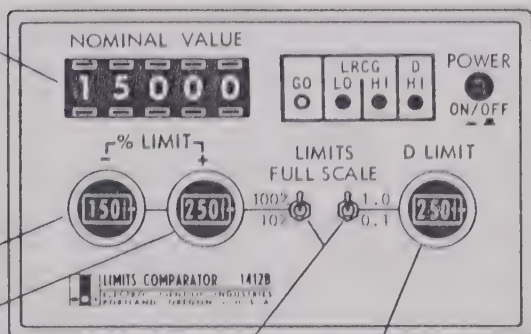
Model 254:

Function and Range settings



Model 1412B:

Nominal value setting



- % Limits setting

+ % Limits setting

LIMITS FULL SCALE Toggle switches settings

D Limit setting



connect the unknown and observe indicator lights. If the LO LED is lit, the unknown is lower than the lower % limit. Similarly, if the HI LED is lit, the unknown is a larger value than the upper % limit. If the D HI LED is lit, the dissipation factor of the unknown exceeds the set limit. If the GO indicator is lit, the unknown value is within the desired limits; in the example, 15 $\mu$ F, +25%, -15%, with a dissipation factor less than 0.0250.

For further operating instructions, see the Model 1412B instruction manual.



## SECTION 3

### CIRCUIT DESCRIPTIONS

#### 3.1 GENERAL DESCRIPTION

When measuring  $C_p$  or  $G_p$ , a voltage is applied across the unknown and range resistor in Figure 3-1. The voltage across the **unknown** is held constant to within one part in several thousand by the 1kHz oscillator feedback control circuit. A current proportional to the value of the unknown impedance is produced through the range resistor. The resultant voltage drop across the range resistor is separated into two vector components by the Phase Sensitive Detectors (PSD) and Reference Voltage Generator (RVG). Receiving gating signals from RVG, the PSD will measure  $G_p$ , the component in phase ( $0^\circ$ ) with RVG, and  $C_p$ , the component at quadrature ( $90^\circ$ ). The selected detector output is then fed to the A/D Converter which has a readout of 1000 counts/volt.

When measuring  $L_s$  or  $R_s$ , a voltage is applied across the unknown and range resistor in Figure 3-1. The voltage across the range resistor is held constant to within one part in several thousand by the 1kHz oscillator feedback control circuit. With a constant current flowing through the unknown, a voltage proportional to the value of the unknown impedance is developed across the unknown. The resultant voltage drop is separated into two vector components by the Phase Sensitive Detector (PSD) and Reference Voltage Generator (RVG). Receiving gating signals from the RVG, the PSD will measure  $R_s$ , the component in phase ( $0^\circ$ ) with the RVG, and  $L_s$ , the component at quadrature ( $90^\circ$ ). The selected detector output is then fed to the A/D Converter which has a readout of 1000 counts/volt.



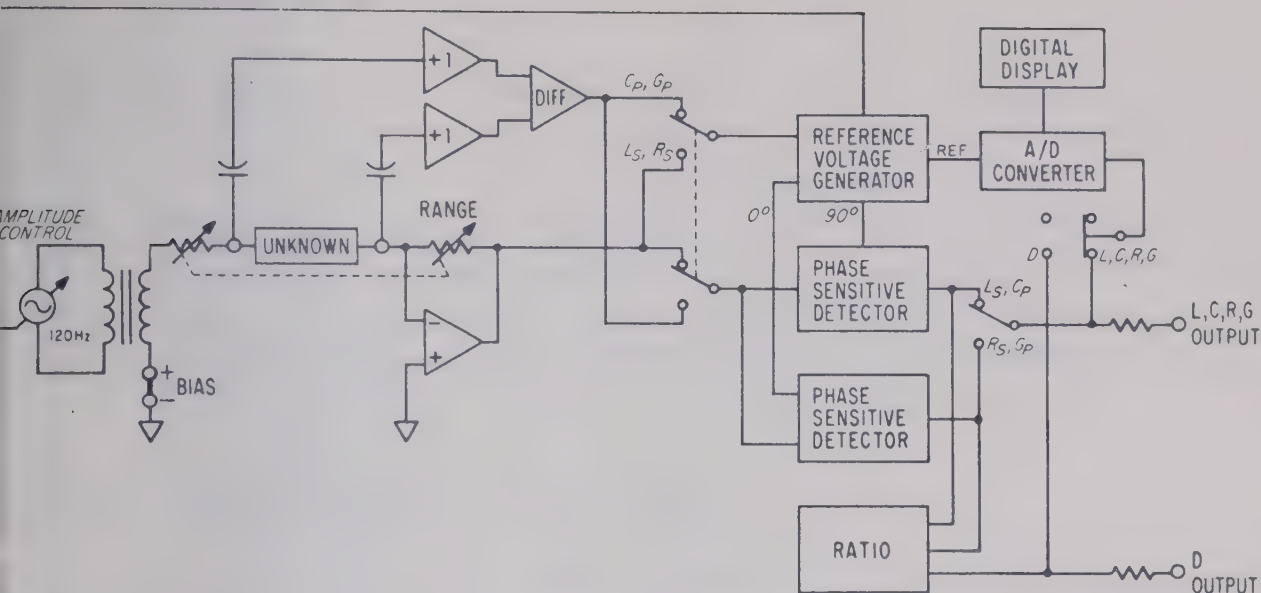


Figure 3-1. Model 254 Simplified Diagram

When measuring the dissipation factor (D) of inductors or capacitors, an analog ratio circuit is used. This circuit compares the loss component ( $R_s$  or  $G_p$ ) to the reactive component ( $L_s$  or  $C_p$ ) and presents a voltage proportional to D to the A/D Converter.

Analog output voltages are available at the rear of Model 254 for the selected function (L, C, R, or G) and simultaneous D (for L or C unknowns).

## 3.2 DETAILED CIRCUIT DESCRIPTIONS

In the following descriptions several conventional resistor networks are involved. To identify which resistor elements are being discussed, the elements are identified by the lower terminal numbers and each is prefixed by a small letter "r". Example: U7 (r1 and r2).



### 3.2.1 120Hz/100Hz Oscillator

The 120Hz/100Hz signal applied to the unknown and range resistor is generated by a power op amp U1, used as a Wien bridge oscillator, with C20, C21, and U19 (r4 and r5) controlling the frequency. Amplitude control for the oscillator is provided by U27 working as a reference voltage null integrator and U35 as the feedback control element. Transformer T2 provides coupling to the unknown and range resistor with provision for inserting bias voltage at rear terminals.

### 3.2.2 Unknown Differential Amplifier

The voltage drop across the unknown is measured by differential amplifier U3-3. Amplifiers U1-3 and U1-4 act as high impedance AC-coupled buffers to prevent loading the unknown. Resistors U6 (r7 and r8) and U7 (r1 and r2) determine the gain (x1) of U3-3. Trimmer R6 is an adjustment for common-mode voltage rejection. Amplifiers U3-2 and U3-3 are switch (U5) selectable gain stages that provide an overall gain of x1, x10 or x100. Trimmers R11 through R17, switched by U4, provide phase adjustments for each range.

### 3.2.3 Range Amplifier

The voltage drop across the range resistor (R22, R24 through R27), selected by U12, is measured by amplifier U1-2. Relay K1 switches R22 in series with the unknown for ranges 20 $\Omega$  and 2 $\Omega$  (or equivalent). For these ranges U36 is used as a gain amplifier of x1 or x10. Other ranges use U36 as a guard amplifier to reduce the effect of shunt impedances on high value unknowns.



## 2.4 Reference Generator and Phase Sensitive Detector

### Reference Generator

AC voltage proportional to the voltage across the unknown or range resistor is generated by U13-2 and U13-3 used in an operational amplifier circuit. For reactive unknowns, amplifier U13-1 is used as AC voltage reference input to the operational rectifier. Gating signals for the in-phase and quadrature phase sensitive detectors are produced by U15-3 and U15-4 used as zero crossing detectors. Trimmer is used for adjustment of the  $90^\circ$  reference gate.

### Phase Sensitive Detectors

Voltage across the unknown ( $R_s$  or  $L_s$ ) or across the range resistor ( $C_p$  or  $G_p$ ) is measured by two phase-sensitive detectors. The in-phase detector consists of amplifiers U17-1 and U30, together with resistor network U23 and switching gate U20. Ripple filtering is provided by R46, R47, C17, and C18. The quadrature ( $90^\circ$ ) detector consists of amplifiers U17-4 and U22, together with resistor network and switching gate U20. Ripple filtering is provided by R41, R42, C14, and C15. Trimmer R45 is used to adjust the full scale value for  $L$  or  $C$ .

## 2.5 Dissipation Factor Circuit

The dissipation factor ( $D$ ) of inductors or capacitors is derived from the ratio of the loss component ( $0^\circ$  phase detector) and reactive component ( $90^\circ$  phase detector). This is done with a pulse-width modulator consisting of integrating amplifier U26 and resistor summing network using U28, R60 and R58. The ratio of  $R$  (or  $G$ ) to  $L$  (or  $C$ ) changes the pulse width ratio of the switching amplifier U27 (with switch U24) to produce a null at the integrator input. Comparator U25-2 acts as the switch driver and is frequency set by the test frequency of the instrument. Amplifiers U27-1 and U27-3 together with



switch U24 are the demodulator which produces an analog voltage proportional to the pulse width variation and scaled to equal the dissipation factor. Trimmer R52 adjusts full scale D value.

### 3.2.6 Overload Blanking Circuit

U15-1 is a comparator amplifier. It monitors the signal levels of the phase detector input and the level regulator amplifier U27-4. When either level exceeds its limit, comparator U15 goes low. This output is combined with a digital overrange signal at the input of a NAND gate of U29 to provide a display blanking output.

### 3.2.7 Analog to Digital Converter

The A/D converter resides in U31 (MC14433) which is a CMOS dual-slope integrating converter. This circuit provides a multiplexed output which is decoded and displayed by a plug-in circuit assembly (42916).

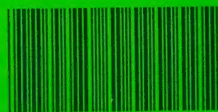
### 3.2.8 Function and Range Programming

A bipolar PROM (U33) stores the necessary range and function programming information for Model 254. The stored program has 32 addresses each with 8 bits of data. These addresses are reached by 2 function bits and 3 range bits which are set by the front panel switches.





MP MASTER



MA30444